When the seasons don't fit

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SUPPORTING INFORMATION – Dietz et al

Details of the Analysis of Primary Molt of Individual Primaries (a), Body Mass and Size Comparison (b), and General Primary Molt Analysis (c)

(a) Results of the Individual Primary Molt Analyses

To test if the overall proportion of feather mass grown (PFMG) increased linearly with time, a requirement for the molt models of [42] and [43], we calculated primary molt models for each individual primary and for each age and sex class (Type 2 and Type 4, [41,42]). The molt index for the individual primary models is based on feather growth scores and does not use information on primary masses. In free-living adults, Type 2 duration estimates up to primary 5 were clearly inconsistent with observed phenology, whereas Type 4 estimates were clearly consistent; for the outer primaries, Type 2 estimates were consistent and Type 4 ones inconsistent (Tables S1 and S2). Therefore we used Type 4 parameters for primaries 1 through 5 and Type 2 parameters for primaries 6 and higher to test if PFMG of the average adult bird increased linearly with time (cf. [70,82]). For second-years, only Type 2 parameters were used as all birds were permanently present in the area (Table S3). Also for captive adults individual primary models were calculated (Table S4). For each group, the average cumulative feather growth was calculated for each primary. These results were converted to feather growth scores from which PFMGs were calculated as in [41]. The estimated cumulative PFMG increased linearly with time in all groups (Fig S1), and the data fulfilled the requirements of the general model.

The results of the individual primary molt models could also be used to investigate how overall molt duration differences were established. Primary molt took a shorter time to complete in lighter than in heavier primaries (Fig. S2). In captive adults, molt duration increased with relative primary mass, while in free-living adults molt duration initially decreased during the first half of molt, up to primary 5. During this period the highest number of primaries was growing simultaneously in free-living adults (ca. four; inset graph). Molt duration of the last primaries (9 and 10) was also shorter in free-living adults than in captive adults. However, as the 95%-confidence intervals of molt duration overlapped between free-living and captive adults for each primary, the differences were not significant.

Table S1. Estimates (with asymptotic standard errors) of individual primary models of Types 2 and 4 for free-living adult male red knots.

Primary	Type 2			Type 4			Sample size by molt status		
	Start	SD start	duration	start	SD start	duration	not started	active	finished
P1	208 ± 2.0	13 ± 3.4	28 ± 2.0	223 ± 3.0	11 ± 2.9	15 ± 2.5	0	146	398
P2	208 ± 2.0	13 ± 3.4	28 ± 2.0	223 ± 3.0	10 ± 2.9	15 ± 2.5	0	146	398
P3	211 ± 1.8	12 ± 3.3	26 ± 1.8	224 ± 2.9	10 ± 2.8	14 ± 2.4	6	143	395
P4	218 ± 1.4	12 ± 3.0	21 ± 1.5	229 ± 3.0	10 ± 2.8	12 ± 2.3	29	143	372
P5	228 ± 1.0	11 ± 2.7	18 ± 1.2	235 ± 3.8	11 ± 2.9	12 ± 3.3	83	158	303
P6	235 ± 0.9	11 ± 2.7	17 ± 1.1	242 ± 3.6	10 ± 3.0	12 ± 2.8	141	158	245
P7	244 ± 0.8	12 ± 2.7	20 ± 1.2	237 ± 3.2	12 ± 3.5	27 ± 3.4	226	178	140
P8	254 ± 0.9	13 ± 3.0	23 ± 1.5	249 ± 4.8	15 ± 5.6	29 ± 5.8	312	169	63
P9	266 ± 1.1	14 ± 3.9	21 ± 1.9	278 ± 14.8	21 ± 12.7	23 ± 14.0	405	108	31
P10	279 ± 2.1	19 ± 5.9	19 ± 2.6	349 ± 39	9 ± 14.1	1 ± 7.2	465	57	22

Table S2. Estimates (with asymptotic standard errors) of individual primary models of Types 2 and 4 for free-living adult female red knots.

primary	Type 2			Type 4			Sample size by molt status		
	Start	SD start	Duration	start	SD start	duration	not started	active	finished
P1	205 ± 1.1	9 ± 2.0	27 ± 1.4	215 ± 1.9	8 ± 1.8	16 ± 1.9	0	211	559
P2	205 ± 1.1	9 ± 2.0	27 ± 1.3	216 ± 1.9	8 ± 1.8	16 ± 1.9	3	212	555
P3	209 ± 0.9	9 ± 1.9	24 ± 1.1	219 ± 1.9	7 ± 1.7	13 ± 1.8	17	201	552
P4	215 ± 0.8	8 ± 1.9	19 ± 1.0	226 ± 2.1	6 ± 1.8	9 ± 1.8	58	181	531
P5	222 ± 0.7	9 ± 1.9	17 ± 0.9	229 ± 1.9	7 ± 1.7	10 ± 1.8	121	174	475
P6	230 ± 0.6	8 ± 1.8	16 ± 0.9	233 ± 1.9	7 ± 2.0	13 ± 1.9	201	184	385
P7	237 ± 0.6	8 ± 1.7	20 ± 0.9	233 ± 1.7	9 ± 2.2	25 ± 2.0	287	231	252
P8	248 ± 0.6	9 ± 1.9	21 ± 1.0	247 ± 2.2	10 ± 2.4	22 ± 2.4	401	214	155
P9	260 ± 0.8	12 ± 2.7	20 ± 1.2	251 ± 5.0	17 ± 6.4	32 ± 6.0	531	168	71
P10	269 ± 1.0	14 ± 3.6	21 ± 1.7	263 ± 18.5	42 ± 28.7	62 ± 32.2	602	138	30

Table S3. Estimates (with asymptotic standard errors) of individual primary models of Types 2 and 4 for free-living second-years red knots (sexes combined).

primary	Type 2			Sample size by molt status		
	Start	SD start	Duration	not started	active	finished
P6	187 ± 2.3	10 ± .13	27 ± 2.5	5	213	368
P7	201 ± 0.9	11 ± 2.5	26 ± 1.5	67	282	237
P8	214 ± 0.7	11 ± 1.2	26 ± 2.3	225	203	158
P9	226 ± 0.9	12 ± 2.6	24 ± 1.3	340	135	111
P10	236 ± 1.1	13 ± 2.9	26 ± 1.6	403	133	50

Note: For P1 to P5 no or insufficient data on active molt was available.

Table S4. Estimates (with asymptotic standard errors) of individual primary models of Type 2 for captive adult male and female red knots.

Primary	male			Sample size by molt status			female			Sample size by molt status		
	start	SD start	duration	not started	active	finished	start	SD start	duration	not started	active	finished
P1	201 ± 2.4	24 ± 6.9	12 ± 2.1	116	27	323	--	--	--	37	8	105
P2	202 ± 2.4	24 ± 7.0	12 ± 2.1	117	28	321	202 ± 2.6	10 ± 4.2	14 ± 3.2	37	12	101
P3	203 ± 2.4	24 ± 6.8	14 ± 2.2	120	33	313	205 ± 2.6	10 ± 4.0	17 ± 3.3	40	14	96
P4	210 ± 2.4	25 ± 6.8	16 ± 2.4	134	37	295	214 ± 3.0	14 ± 5.5	15 ± 3.5	47	13	90
P5	218 ± 2.6	27 ± 7.5	16 ± 2.4	152	36	278	222 ± 3.4	19 ± 6.9	16 ± 3.8	54	13	83
P6	225 ± 2.7	31 ± 8.1	20 ± 2.7	169	45	252	231 ± 3.8	22 ± 7.8	17 ± 4.0	61	14	75
P7	237 ± 2.8	33 ± 8.5	22 ± 2.8	196	49	221	--	--	--	70	18	62
P8	252 ± 2.9	35 ± 8.9	23 ± 2.9	229	20	187	255 ± 4.3	27 ± 9.4	23 ± 4.8	80	18	52
P9	265 ± 2.9	34 ± 8.8	24 ± 3.0	257	20	159	270 ± 4.6	30 ± 10.4	25 ± 5.1	92	18	40
P10	280 ± 3.2	38 ± 9.9	29 ± 3.3	287	59	120	284 ± 4.9	31 ± 11.1	27 ± 5.5	101	19	30

Note: The models for primaries 1 and 7 for female knots did not converge to a significant solution.

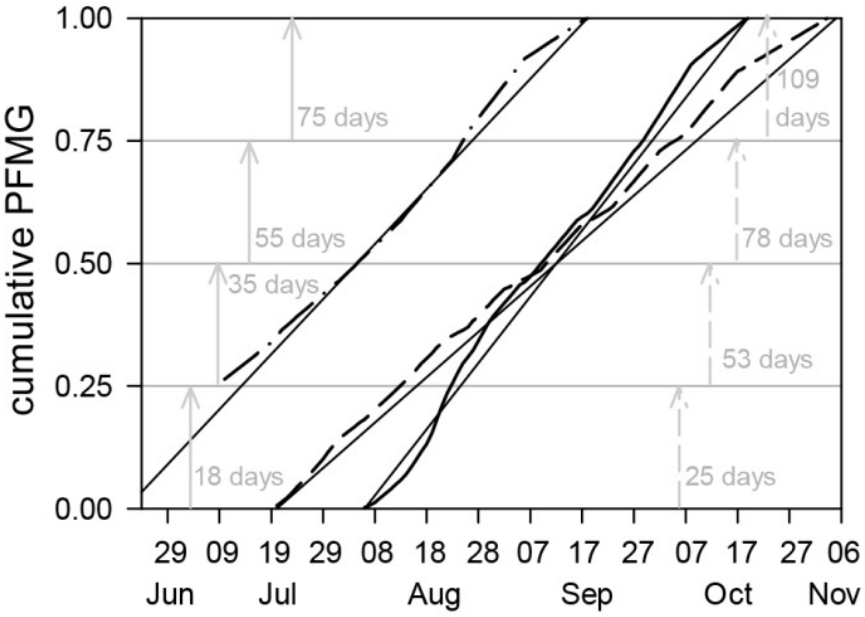

Figure S1. The cumulative proportion of feather mass grown (PFMG) during molt in free-living adult and second-year red knots, and captive adult red knots, determined via the individual primary models. The data were pooled for the sexes because molt models could not be fitted for primaries 1 and 7 in captive females. For second-years we had no or insufficient data for primaries 1-5 (Table S3). Since at the end of molt PFMG equals 1, the PFMG grown by primaries 1-5 could be determined and added to the proportion of feather mass grown obtained from the known primaries. For want of data, we excluded the first 10 days of available data from the graph. The thick lines show cumulative PFMG curves (solid, free-living adults; dashed, captive adults; dash-dot, second-years). The thin lines correspond to uniform growth rates. For second-years this is the estimated uniform growth rate calculated using the mean start date obtained from the general molt models and end date from the individual primary models. The horizontal grey lines indicate the quartiles of PFMG and their durations for free-living adults (continuous arrows) and captive adults (dashed arrows). In all groups PFMG increased sufficiently linearly with time to make them good indices of molt progression.

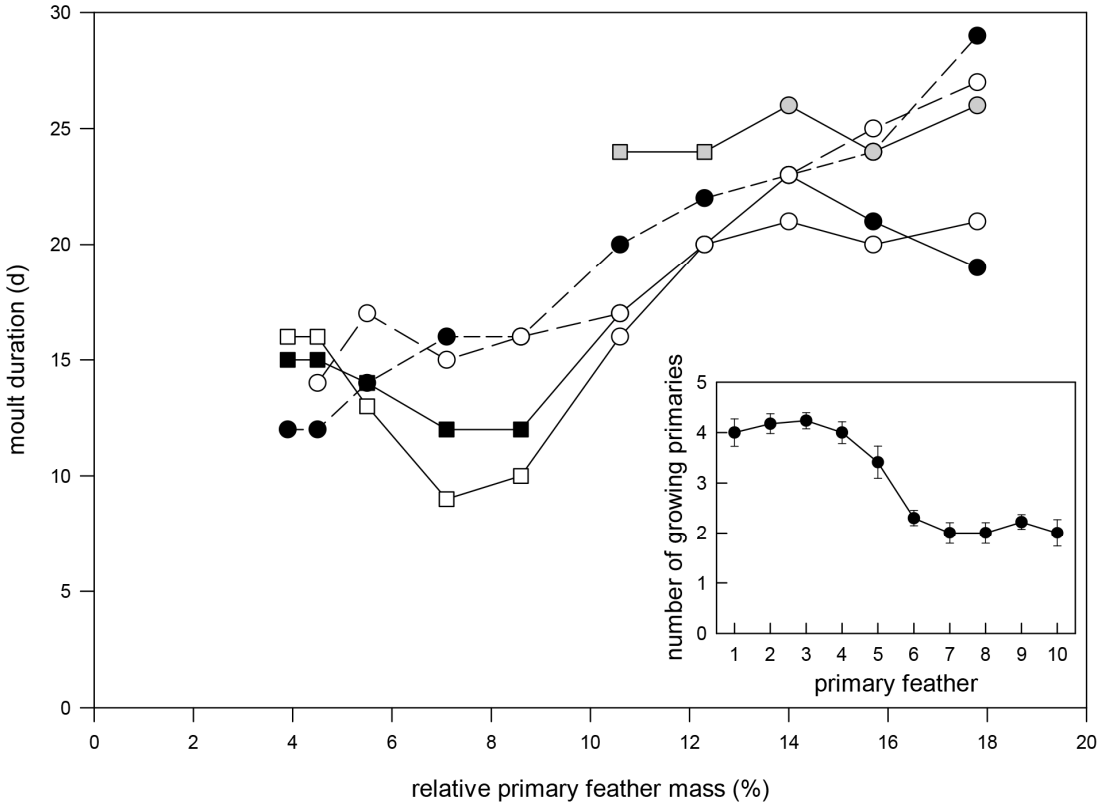

Figure S2. Molt duration of individual primaries versus relative primary feather mass for free-living adult and second-year knots (solid lines) and captive adult red knots (dashed lines). Each point on each curve corresponds to an individual primary as relative primary mass increases with increasing primary number. For adult captive females, the models did not converse to a significant solution for primaries 1 and 7. For second-years we had insufficient data of active molt for primaries 1-5 (Table S3) and data for the sexes were pooled. Closed symbols, males; open symbols, females; grey symbols, second-years; circle, Type 2 model; square, Type 4 model. The inset graph shows the number of simultaneously growing primaries (mean ± SE) for each primary in molt for the average free-living adult knot.

(b) Body Size Characteristics of Free-Living Red Knots

Table S5. Body mass and body size characteristics of free-living second-year and adult red knots that had completed primary molt.

	body mass (g)	wing length (mm)	bill length (mm)	tarsus length (mm)
adult male	139 ± 1.6 (18)[a]	170 ± 0.8 (13)[a,b]	32.7 ± 0.3 (18)[a]	31.8 ± 0.3 (18)
adult female	150 ± 2.1 (25)[b]	175 ± 0.5 (23)[c]	34.3 ± 0.3 (25)[b]	32.1 ± 0.3 (25)
second-year male	138 ± 1.6 (24)[a]	169 ± 0.8 (23)[a]	32.6 ± 0.4 (25)[a]	31.2 ± 0.2 (25)
second-year female	149 ± 1.8 (23)[b]	173 ± 0.9 (24)[b,c]	34.1 ± 0.4 (25)[b]	32.2 ± 0.3 (25)

Note: Sample size is given in parentheses. Not all variables were always determined and occasionally an erroneous number was noted. Groups that differed significantly from each other within a column have different alphabetical subscripts (ANOVA, Tukey post-hoc analysis).

(c) The Results of the Primary Molt Models

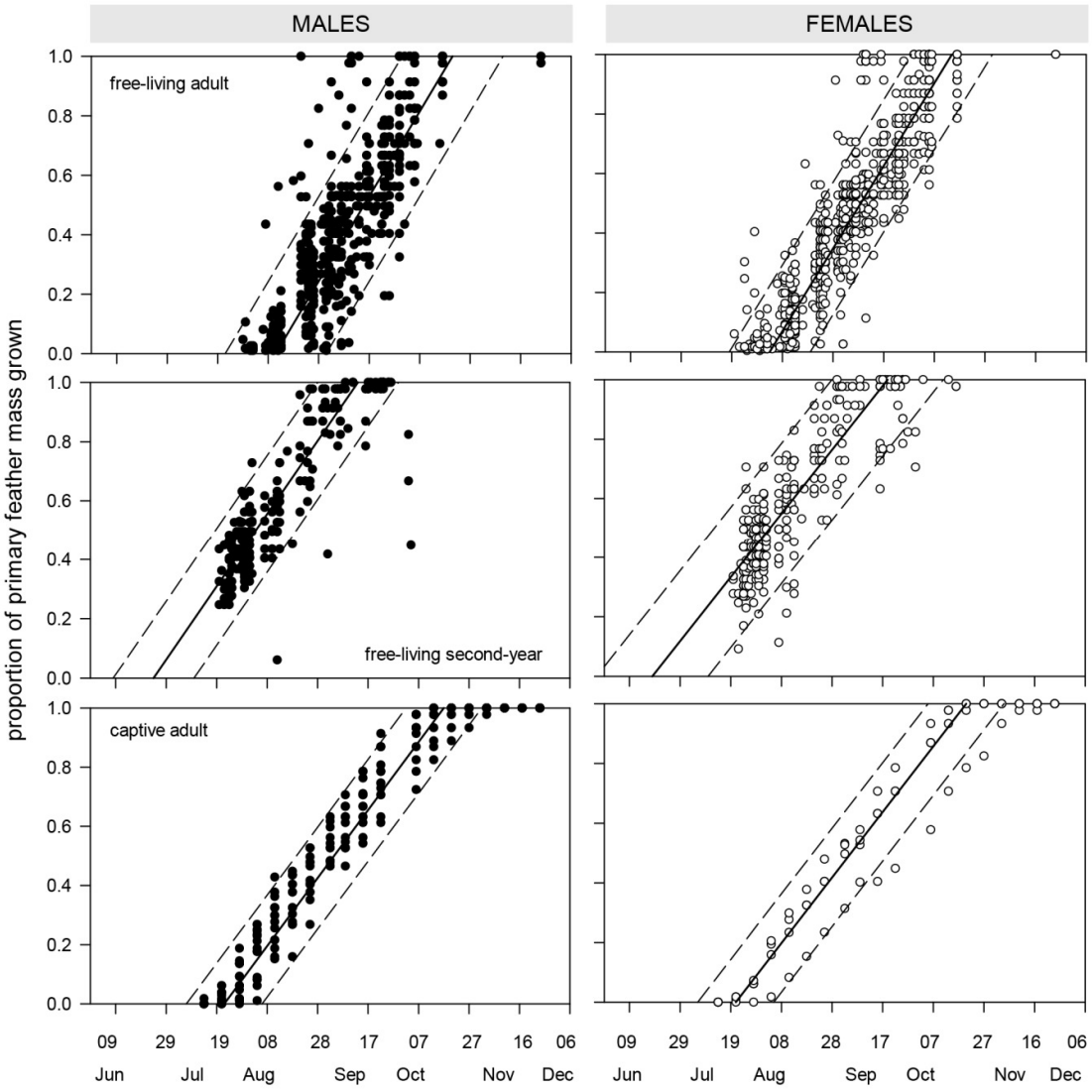

Figure S3. The relationship between the proportion of primary feather mass grown and time of the year for free-living adult and second-year red knots, and captive adult red knots. Left panels, males, closed symbols; right panels, females, open symbols. Solid lines represent the general molt models, dashed lines give the 95% confidence intervals.

(d) Final Estimates of the Primary Molt Models

Table S6. Final estimates (with asymptotic standard errors for free-living red knots and SE for captive knots) of general molt parameters.

group	molt parameters				sample size by molt status			range individual molt models			
	start	SD start	duration	end	none	active	finished	start min	start max	duration min	duration max
SYM	175 ± 1.3	8 ± 1.6	81 ± 2.1	256	0	233	25				
SYF	169 ± 1.8	11 ± 2.4	93 ± 2.9	262	0	294	25				
FAdM	223 ± 1.1	10 ± 2.0	70 ± 2.1	293	0	492	18				
FAdF	215 ± 0.7	8 ± 1.4	72 ± 1.3	287	0	649	25				
CAdM	203 ± 1.6	7.5	87 ± 1.5	290 ± 1.9	55	240	144	191	212	75	100
CAdF	202 ± 2.3	7.8	93 ± 2.3	295 ± 4.7	27	137	70	192	213	80	107
CAdMf	201 ± 1.6	5.7	85 ± 2.2	289 ± 2.5	19	156	72	194	212	75	100
CAdFf	204 ± 3.5	6.9	92 ± 4.2	296 ± 7.4	6	52	18	199	214	85	104

Note: A Type 4 model was used for free-living adult red knots and a Type 2 model for second-years. For captive knots, the results are the means of the individual molt models. Range of the start and duration of individual bird models of the captive birds is given in the last columns. Start and end date are given in Julian day. Group abbreviations: SYM, second-year males; SYF, second-year females; FAdM, free-living adult males; FAdF, free-living adult females; CAdM, captive adult males 2009; CAdF, captive adult females 2009; CAdMf, captive adult males first molt; CAdFf, captive adult females first molt